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# Integrating the ecosystem-based approach into municipal climate adaptation strategies: The case of Germany

Teresa Zölch [a, *], Christine Wamsler [b], Stephan Pauleit [c]

[a] Centre for Urban Ecology and Climate Adaptation, Technical University of Munich, Munich, Germany
[b] Lund University Centre for Sustainability Studies and Centre for Societal Resilience, Lund University, Lund, Sweden
[c] Chair for Strategic Landscape Management and Planning, Technical University of Munich, Freising, Germany

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ABSTRACT

Climate change impacts are a key challenge for sustainable urban development. To address this challenge, ecosystem-based adaptation (EbA), i.e., the use of ecosystem services and biodiversity to help people adapt to climate change, is increasingly being considered as an alternative or complement to traditional, engineering-based approaches (increasingly also known as nature-based solutions). However, little research on ecosystem-based adaptation has been carried out in urban areas, and empirical evidence of its effectiveness and uptake in strategic adaptation planning is particularly lacking. Against this background, this study investigates the implementation of urban EbA in strategic adaptation planning. Based on a comparative analysis of all German municipalities with more than 100,000 inhabitants, it examines the integration of EbA into municipal adaptation strategies. The results show that there is, so far, no comprehensive uptake of the EbA concept. While current strategies differ significantly in their type, structure, scope, maturity and content, overall the EbA concept remains implicit. 76% of the assessed strategies include some kind of ecosystem-based adaptation measures, which focus on enhancing the conservation, restoration, creation or sustainable management of ecosystems, and 25% of all strategies highlight the multiple benefits of these measures. However, comprehensive approaches are missing. We conclude that better policy support and comprehensive mainstreaming of EbA (e.g., through more distributed urban governance, science-policy integration, combined top-down policies and bottom-up activities) is urgently needed to foster sustainable urban development.

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## 1. Introduction

In Europe, climate change is expected to lead to increased climatic variability and extremes such as heatwaves and heavy rain (IPCC, 2014). Cities are particularly vulnerable for several reasons (Revi et al., 2014), including the density of built structures, the extent of sealed surfaces and the limited number of green spaces (EEA, 2012; Wamsler, 2014).

Consequently, many cities are putting in place climate change adaptation strategies that support urban planning activities and increase resilience (Perks, 2011). The strategies can use various forms of applied actions and activities (EEA, 2012; Noble et al., 2014). Hard approaches (grey infrastructure) refer to engineering measures that can withstand climatic variability and extremes (e.g. levees, technical shading, irrigation systems), while soft measures encourage adaptive behaviour by, for example, providing information and incentives (EEA, 2012). In contrast, green infrastructure aims at increasing urban resilience through the provision of ecosystem services in the form of green and blue urban spaces (EC, 2009). These services provide benefits to society through ecosystem functions (Daily, 1997; MEA, 2005).

Ecosystem-based adaptation (EbA) is the term used to refer to ecosystem services and biodiversity that help society to adapt to climate change impacts (CBD, 2009). Several authors have claimed that it provides a flexible, cost-effective and broadly-applicable approach to climate change adaptation compared to conventional approaches (Vignola et al., 2009; Jones et al., 2012). Others have argued that the adoption of EbA generates multiple co-benefits for urban planning (Wamsler et al., 2014), such as increased biodiversity (Ojea, 2015), more recreation opportunities (Doswald et al.,

* Corresponding author. Technical University of Munich (TUM), Centre for Urban Ecology and Climate Adaptation (ZSK), Arcisstraße 21, 80333, München, Germany.
*E-mail addresses:* teresa.zoelch@tum.de (T. Zölch), christine.wamsler@lucsus.lu.se (C. Wamsler), pauleit@tum.de (S. Pauleit).

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2014) and climate change mitigation (Jones et al., 2012; Noble et al., 2014). Moreover, the concept is said to support participatory approaches, which also allows the consideration of stakeholders' differing interests (Nesshöver et al., 2017; Wamsler, 2017).

The potential contribution of EbA to effective climate change adaptation has been addressed in the literature. However, several reviews of current research on EbA have concluded that although EbA has shown positive effects, a lack of knowledge about related governance structures (Ojea, 2015; Brink et al., 2016) and the effectiveness of current applications (Munroe et al., 2012; Doswald et al., 2014) have hindered its wider implementation.

In addition, research on the integration of EbA into local adaptation planning is still in its infancy, particularly in urban planning (Brink et al., 2016). Geneletti and Zardo (2016) carried out an initial analysis of the inclusion of EbA measures in adaptation plans in European cities pioneering climate adaptation. Pathways for mainstreaming EbA in municipal governance and at project level have also been investigated in some case study cities in South Africa (Pasquini and Cowling, 2014), Sweden (Wamsler et al., 2014, 2016) and Germany (Wamsler, 2015; Wamsler and Pauleit, 2016). However, systematic analyses of how the EbA concept is integrated into municipal adaptation strategies are lacking.

Against this background, this study expands knowledge on the role of EbA in strategic adaptation planning. Based on a comparative analysis, it examines the integration of EbA into municipal adaptation strategies in Germany, in order to answer the following research questions:

1) How and in which context is the EbA concept integrated into municipal adaptation strategies?
2) What types of EbA measures can be identified?
3) Why are these measures seen as useful? What are their suggested or expected benefits?

Section 2 presents the applied methodology for data collection and analysis, which is based on a conceptual framework for assessing EbA in strategic planning. Section 3 assesses and compares the differences, synergies and gaps in the integration of EbA into municipal adaptation strategies in Germany. The results are then discussed in relation to practical applications of EbA and potential benefits (Section 4). Finally, Section 5 highlights the key aspects that are necessary to ensure more effective integration of EbA into urban planning.

## 2. Methodology

The approach consisted of a quantitative and qualitative content analysis (Roe, 1994), which is introduced in section 2.3. The documentation used for the analysis was based on a nationwide sample of municipal adaptation strategies. The criteria for the analysis were derived from the conceptual framework presented in Section 2.1.

The geographical focus was Germany. This sample is particularly interesting as the political discourse about EbA has here received increasing interest in recent years. For example, the Federal Agency for Nature Conservation has promoted EbA by publishing a review of good, ecosystem-based practices in various sectors (Doswald and Osti, 2011), and funded a national project on ecosystem-based approaches for climate change mitigation and adaptation (BfN, 2012). Moreover, the use of multi-functional green spaces for climate change adaptation was a key aspect of the Federal Government's 2011 Action Plan for Climate Change Adaptation, which provides recommendations for action at lower policy levels (Deutsche Bundesregierung, 2011).

### 2.1. Conceptual framework

Fig. 1 presents the main components of the EbA concept. These components provided the basis for the analysis of the identified municipal adaptation plans. The EbA concept assumes that ecosystems provide services that help people to adapt to the impacts of climate change (CBD, 2009; Chong, 2014). In urban areas, the term *ecosystem services* refers to services provided by a network of natural and semi-natural, managed, green and blue spaces (Bolund and Hunhammar, 1999).

There are four broad categories of ecosystem services: provisioning, habitat/supporting, regulating and cultural (MEA, 2005). Biodiversity is explicitly included in the Convention of Biological Diversity's (CBD) definition of EbA. It is integral to the functioning of ecosystems and falls into the category of supporting services, which provide habitats and maintain species diversity (CBD, 2009; TEEB, 2011). All four categories have adaptation benefits. Regulating services (e.g. local temperature regulation) are considered to directly moderate climate and hydrology (e.g. Gaffin et al., 2012; Uy and Shaw, 2012), while the other services have indirect benefits. For example, the provision of recreation facilities in green spaces is considered to be a cultural service that contributes positively to physical and mental health, while the supply of fresh water that is stored and purified by ecosystems is deemed a provisioning service (Foster et al., 2011; TEEB, 2011).

The term *EbA measures* refers to urban ecosystems that provide services at different scales, from the individual building (e.g. green roofs) to an entire city (e.g. green corridors) (Doswald et al., 2014; Geneletti and Zardo, 2016). EbA measures are designed to support climate change adaptation (e.g. adaptation to heat or flooding) through the provision of at least one ecosystem service (Doswald et al., 2014; Brink et al., 2016). They therefore rely on the presence of relevant green or blue urban infrastructure and concern the conservation, restoration, creation and/or sustainable management of ecosystems (Doswald et al., 2014). According to the presented relations, EbA measures can be characterised in four ways:

- The aim and type of measure (e.g. the promotion of green roofs);
- The urban ecosystem/green infrastructure/ecological structure (e.g. a park) on which the EbA measure relies;
- The ecosystem service that the measure is expected to provide for climate change adaptation, and the climate change impact it is designed to mitigate;
- The measure's multiple benefits, if known/mentioned.

### 2.2. Data collection

The analysis focused on the municipal adaptation strategies of German cities with more than 100,000 inhabitants (Statistisches Bundesamt, 2014), which fulfilled the following criteria:

1) The municipal adaptation strategy anticipated increased exposure to heat events and/or flash floods;
2) The adaptation strategy was either stand-alone or an integral part of a climate change mitigation or urban development programme;
3) The strategy was publicly available in January 2015.

A total of 34 documents were identified and assessed (a list of the documentation that was analysed is provided in Appendix A).

### 2.3. Data analysis

A quantitative and qualitative content analysis as described by

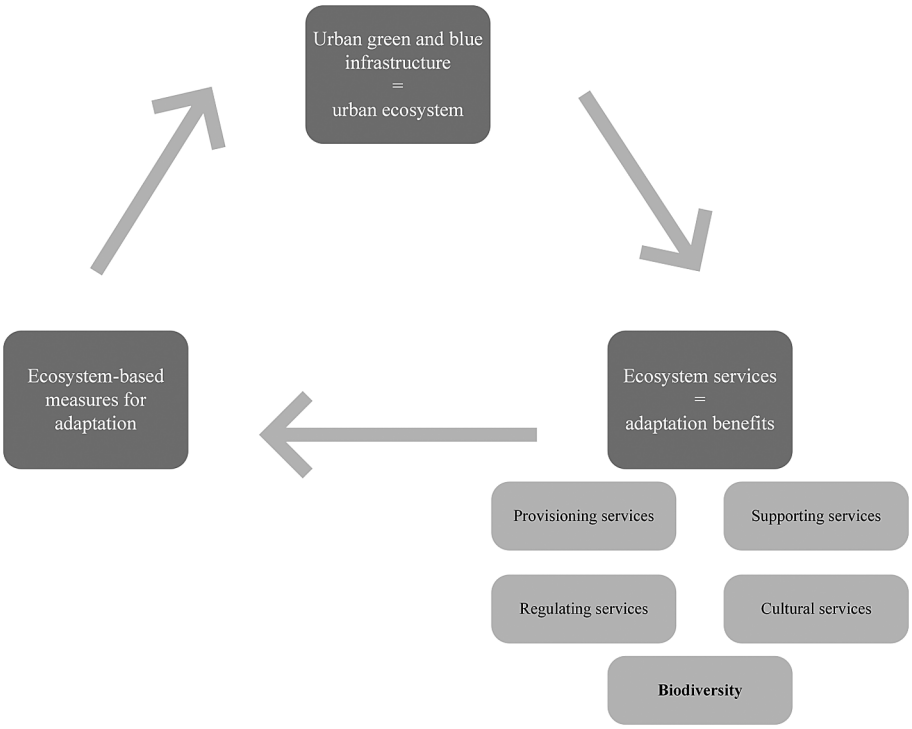


**Fig. 1.** The EbA concept in urban planning.

Roe (1994) and Hansen et al. (2014) addressed the first research question (the aim and type of measure). The selected municipal adaptation strategies were analysed regarding the presence of certain keywords as well as their contexts. Both the keywords and the related analysis criteria were derived from a literature review that lead to the analytical framework presented in section 2.2. As many different terms are used to refer to EbA, the following keywords were used: Ecosystem-based; Ecosystem service – Environmental service; Biodiversity – Biological diversity; Green infrastructure – Green structure – Natural balance – Urban ecology.

Each document was analysed to identify instances of these keywords. The context for each keyword was also recorded and coded. Direct references to the term 'ecosystem-based' were understood to be evidence of conscious uptake of the concept, while indirect references (i.e. the use of terms describing the underlying concepts) were understood as an indicator of a conceptual understanding of related objectives and benefits (Hansen et al., 2014).

In a next step, a second round of coding associated the context of the EbA reference with a theme. Following the work of Baker et al. (2012) on the components of adaptation plans, five themes were identified:

1) General background: the response to climate change and definitions of terms;
2) City-specific background: municipal objectives and activities;
3) Climate change impacts on ecosystems: climate change impacts and adaptation priorities;
4) General and potential adaptation options;
5) Specific adaptation measures: planned, on-the-ground measures.

The subsequent qualitative content analysis focused on specific adaptation measures (fifth bullet point above). First, all adaptation measures that fulfilled the EbA criteria (Section 2.1) were identified, irrespective of whether or not they were explicitly described as EbA measures. Second, the contextual descriptions of the identified measures were examined to assess whether they were characteristic of EbA measures (as described in Section 2.1).

In order to identify elements of green and blue infrastructure in urban ecosystems, the classification developed by Bolund and Hunhammar (1999) was used: specifically, trees, parks/lawns, urban forests, cultivated land and lakes/streams. This list was extended to include 'greening of buildings', 'street and backyard vegetation' and 'strategic measures' following later work (Benedict and McMahon, 2006; Pauleit et al., 2011). Finally, the four broad categories of ecosystem services (provisioning, regulating, supporting and cultural) were divided into 21 individual ecosystem services (Table 1) which can be expected to be provided by EbA measures (TEEB, 2011; Gómez-Baggethun and Barton, 2013).

## 3. Results

### 3.1. Characteristics of municipal adaptation strategies

The 34 municipalities with an adaptation strategy included in this analysis (Appendix A) are evenly distributed across the country, with the exception of a conglomeration of large cities in the Ruhr area of western Germany (Fig. 2). The adaptation strategies (Appendix A) are significantly different in terms of their type, structure, scope and maturity. Nineteen are stand-alone policies, 14 are part of municipal mitigation strategies, and one is part of an urban development strategy. Their length ranges from four to 350 pages.

All of the strategies were applied between 2009 and 2014, hence following the establishment of the EbA approach on the international agenda in 2008 (IUCN, 2008; Girot et al., 2012). They were developed by a variety of stakeholders, including the municipality itself (e.g. Berlin, Hamburg), external service providers (e.g. Köln, Bonn), research institutions, or as a research project deliverable

**Table 1**
Detailed list of ecosystem services (adopted from TEEB, 2011; Gomez-Baggethun and Barton, 2013).

| Classification of urban ecosystem services | |
|---|---|
| Provisioning services | Food supply |
| | Raw materials supply |
| | Fresh water supply |
| | Medicinal resources |
| Regulating services | Urban temperature regulation |
| | Air quality regulation |
| | Carbon sequestration and storage |
| | Water flow regulation and run-off mitigation |
| | Moderation of extreme events |
| | Waste-water treatment |
| | Pollination |
| | Erosion protection |
| | Maintenance of soil fertility |
| | Biological control |
| Supporting services | Habitat provision |
| | Maintenance of biological diversity |
| Cultural services | Recreation |
| | Tourism |
| | Aesthetic appreciation |
| | Education |
| | Spiritual experience and sense of place, i.e., where ecosystems are related to spiritual values |

**Fig. 2.** Large German cities with adaptation strategies. The municipal mitigation and urban development strategies were selected as they contained extra sections specifically focusing on climate change adaptation activities.

(e.g. Dresden, Jena).

The integration of climate change adaptation into municipal mitigation strategies ranged from naming it as a secondary objective (e.g. Bonn) to presenting it as a stand-alone section (e.g. Chemnitz). Overall, stand-alone adaptation strategies were more comprehensive and detailed than others.

Regarding their content, almost all strategies identified extreme heat events, heavy rain events, and flooding as the climate change impacts that needed to be addressed by ecosystem-based approaches. Average temperature increases, extreme wind events, changing precipitation regimes, decreased/increased precipitation, and sea level rise were also found in some strategies.

### 3.2. Representation of the ecosystem-based approach

None of the municipalities directly used the term 'ecosystem-based' to refer to their adaptation activities. However, most strategies (82%) included indirect references to the concept's underlying components, reflected in the use of related keywords such as 'ecosystem service', 'biodiversity' and 'green infrastructure'. The keywords 'biodiversity' and 'biological diversity' were mentioned in 68% of strategies as illustrated in Fig. 3; four strategies included them more than 30 times each (Jena, Karlsruhe, Dresden, Saarbrücken). The keyword 'ecosystem service' was found in 21% of strategies, while 'green infrastructure' was found in 41%. The frequency of references to those EbA-related keywords ranged from 1 to 20.

The most extensive and elaborated strategies were developed by Jena, Karlsruhe, Dresden and Saarbrücken. The Saarbrücken strategy contained most references to biodiversity, and was the only example of adaptation strategy that was integrated into an urban development programme (i.e. nature conservation plays an important role in a broader document).

With respect to the five themes identified in Section 2.3, the context analysis showed that almost half of the keywords (47%) appeared in the section of the documentation focused on specific adaptation measures, while the other half were relatively evenly distributed across the other four themes. With respect to individual keywords, in all cases, most references to EbA related to specific adaptation measures, while 'biodiversity' was also frequently included in the context of climate change impacts (Fig. 4).

Regarding the effectiveness of EbA measures, only Berlin and Köln attempted to quantify their impact through microclimate simulations that showed a reduction in air temperature as a result of implementing greening programmes (e.g. street trees or facade greening) (Senatsverwaltung für Stadtentwicklung Berlin, 2011; Grothues et al., 2013).

### 3.3. EbA measures in municipal adaptation strategies

Fig. 5 shows that the percentage of EbA measures compared to all adaptation measures included in municipal adaptation strategies varied considerably. Many cities provided a comprehensive list of planned adaptation measures (ranging from 0 to 157) together with more-or-less detailed explanations. For instance, the city of Jena has developed a strategic document that provides 118 detailed descriptions of measures; Karlsruhe listed 157, and Dresden 74 adaptation measures in their respective strategies. In contrast, three of the 34 cities did not include any planned adaptation measures (Oberhausen, Bonn, Essen), while another five cities referred to conventional adaptation measures, but did not list ecosystem-based measures (Essen, Wuppertal, Halle (Saale), Erfurt, Würzburg).

Even though none of the assessed climate change adaptation strategies refer directly to the EbA concept, 76% of them referred to

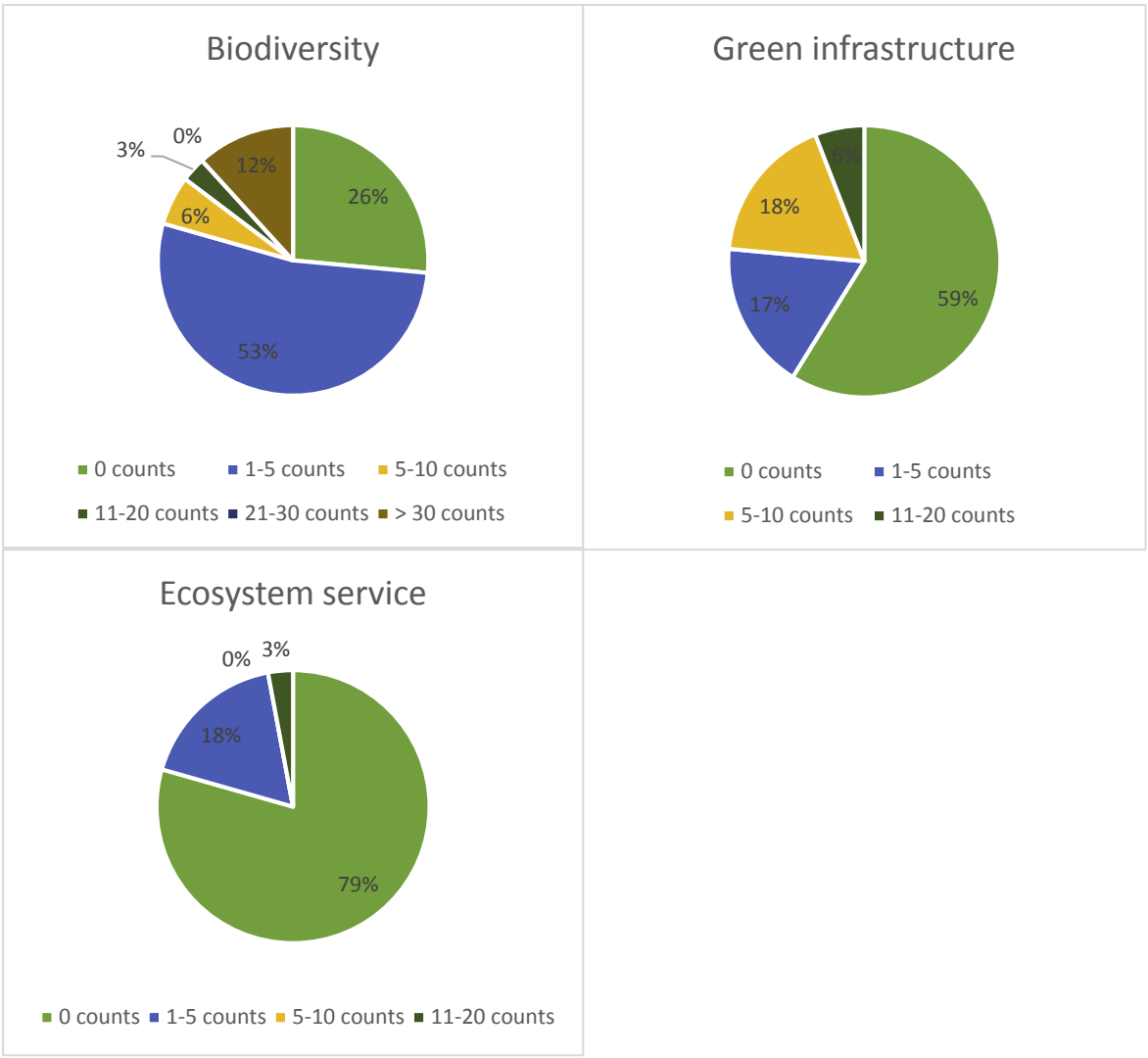


**Fig. 3.** Frequency of references to EbA-related keywords in municipal adaptation strategies (n = 34). As the keyword 'ecosystem-based' was not found, it is not included.

EbA related measures as introduced in the analytical framework. The percentage of EbA measures compared to conventional, engineering-based measures ranged from 15 to 100%. In three cities, all adaptation measures could be linked to EbA: Munich (integrated into a mitigation strategy), and Bremen and Mülheim (stand-alone adaptation strategies). In 12 cities EbA measures were evenly distributed (26–50%) compared to all adaptation measures.

An analysis of the characteristics of the 363 EbA measures that were identified led to their classification into four categories: conservation, restoration, sustainable management and creation of ecosystems. Ecosystem creation was mentioned most frequently (39%) and included all measures that suggested an increase in urban greening (e.g. tree planting or installing green roofs and facades) (Table 2). Many measures referred to the sustainable management of ecosystems, which involves the development of connected habitats, sustainable irrigation practices in public green spaces, or choosing climate-robust plant species (Doswald et al., 2014). Sixty-one measures can be assigned to more than one category (Table 2).

The urban ecosystems used or created by EbA measures ranged from green buildings to urban forests (Table 2). Parks/lawns was the most frequently-used ecosystem (93 instances) for individual measures. Strategic measures, which do not focus on improving a single ecosystem, were the second-largest group. They represent a strategic approach to improving the ecosystems of an entire city. In contrast, greening of buildings (19 instances) was the least-frequently-used measure. This structure focuses specifically on green roofs and facades, unlike more general ecosystems that cover a large range of activities such as street and backyard greening or adding parks/lawns. A total of 27 of measures were related to more than one urban ecosystem (e.g. conservation and development of connected green, garden and forest spaces, and the greening of backyards, roofs and facades).

Regarding the expectations for integrating EbA measures into adaptation strategies, 14 of the 21 individual ecosystem service categories were mentioned (Fig. 6). Regulating services were cited most often (303 instances). Among these services, 'urban temperature regulation' was used 121 times to refer to measures such as the conservation of fresh air corridors and greening facades. 'Run-off mitigation' was achieved by, for example, greening roofs and unsealing impervious surfaces (54 instances), while 'moderation of extreme events' through, for example, climate-adapted species selection was used 59 times.

Supporting services were the second-largest group. There were

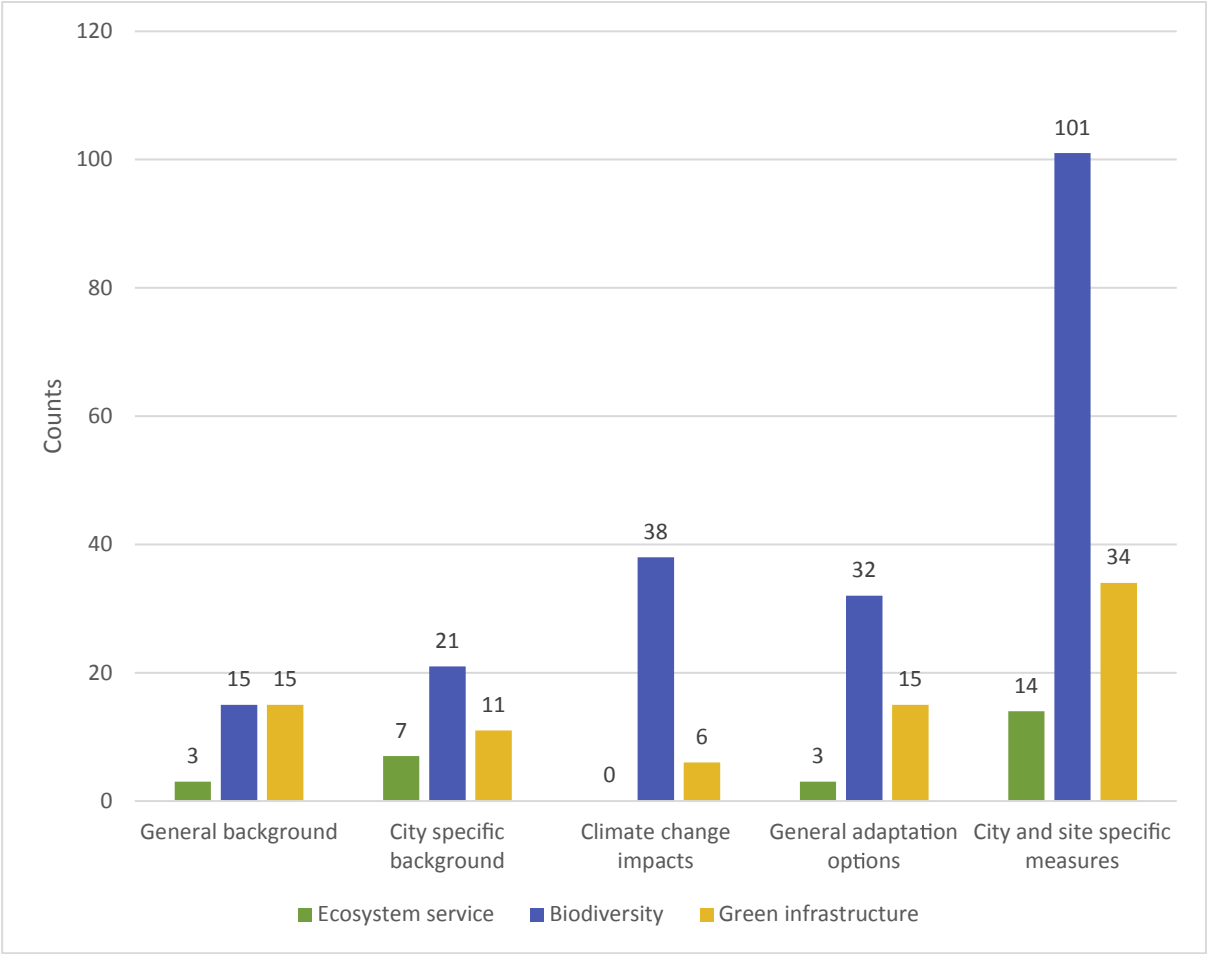


**Fig. 4.** Themes associated with EbA-related keywords.

13 instances of 'habitat provision' and 38 instances of 'maintenance of genetic diversity'. Cultural and provisioning services were also mentioned, but to a lesser extent. The provision of recreation opportunities such as the enhancement of green spaces was referred to 16 times and is the most relevant service in the two groups. Seven ecosystem services (food supply, raw material supply, medicinal resources, waste-water treatment, pollination, tourism, and spiritual experience and sense of place) were not mentioned in any of the adaptation strategies (Fig. 6).

The number of ecosystem services referred to per municipality is shown in Appendix B. An average of 11 (mainly regulating) ecosystem services were mentioned and this service was referred to most frequently in almost all cities. Mülheim was the only exception; it mentioned supporting and cultural services, but not regulating services. In cases where no instances were recorded, no adaptation or EbA measures were identified.

The strategies of Jena, Dresden and Köln mentioned ecosystem services as objectives for their measures most frequently (41, 38 and 31 times, respectively) and listed many EbA measures (37, 23 and 43 measures, respectively). Although the Duisburg strategy included most references to EbA measures (62), it referred to individual ecosystem services less often (22).

In approximately 25% of cases, one reason for implementing individual EbA measures was the provision of a multitude of benefits. In most cases this concerned the provision of a regulating service, together with up to three other types of ecosystem service. For example, Duisburg expected a reduction in the extent of sealed surfaces to lead to a reduction in urban temperature and run-off, the maintenance of soil fertility and securing fresh water supplies.

With respect to individual adaptation strategies, 48% included EbA measures that had multiple objectives. For example, Bremen listed five, multi-objective measures, aimed at climate change adaptation and mitigation, maintaining soil fertility, carbon sequestration and storage. Similarly, Munich's mitigation strategy included several adaptation measures that were aimed at carbon storage, recreation facilities and climate change education (including mitigation and adaptation). Dresden's strategy contained the most multi-benefit EbA measures in absolute terms.

## 4. Discussion

Our results and their comparison with other literature highlight key patterns in the use of EbA in current municipal adaptation strategies. The following sections discuss their benefits and implications.

### 4.1. EbA in strategic adaptation planning

Consistent with Pasquini and Cowling (2014) and Wamsler et al. (2016), this study found that the EbA concept and terminology has not yet been disseminated to the local policy level. Nevertheless,

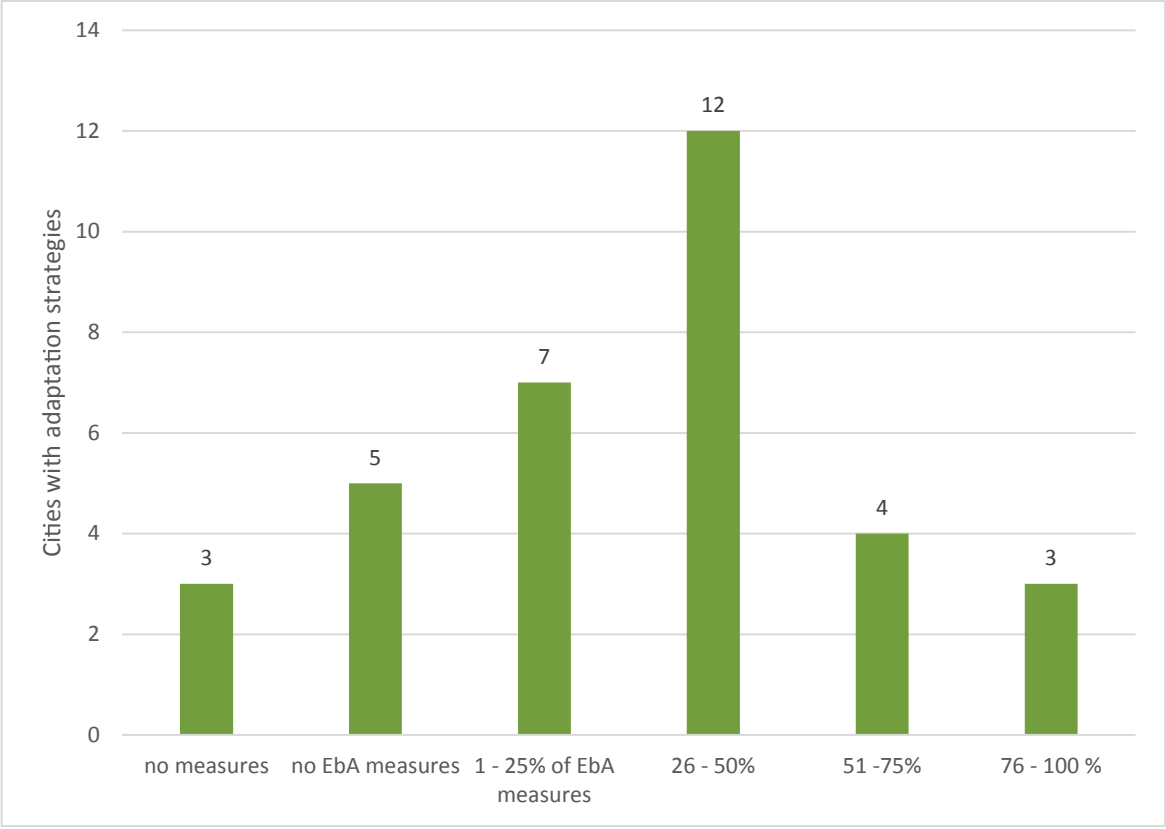


**Fig. 5.** Percentage of EbA-related measures in relation to all adaptation measures included in municipal adaptation strategies (n = 34).

**Table 2**
Types of EbA measures and the ecosystems they use/create.

| Type of EbA measure | Total number |
|---|---|
| Ecosystem conservation | 71 |
| Ecosystem restoration | 29 |
| Sustainable management of ecosystems | 125 |
| Ecosystem creation | 142 |
| *Number of measures falling into more than one category* | *61* |
| **Type of ecosystem used by measure** | |
| Urban forests | 26 |
| Cultivated land | 16 |
| Parks/lawns | 93 |
| Trees | 36 |
| Street and backyard vegetation | 39 |
| Greening of buildings (green roofs and facades) | 19 |
| Blue infrastructure (e.g. lakes, streams) | 23 |
| Strategic measures | 82 |
| *Number of measures falling into more than one category* | *27* |

most of the analysed strategies included indirect references to the underlying principles of EbA (ecosystem services, biodiversity and green infrastructure), indicating a general understanding of the concept.

There is a lack of attention given to the underlying concept of ecosystem services. This relates to the fact that it is a recent development and that some aspects of it (e.g. monetarisation) have been criticised by municipal staff (Wamsler, 2015). Other potential reasons include the co-existence of 'older' concepts, such as 'green infrastructure', 'landscape' or 'ecological functions' (Albert et al., 2012). Unlike other countries, e.g. Sweden, ecosystem services do not seem to be the main driver for mainstreaming EbA into municipal planning and governance in Germany (Wamsler, 2015; Wamsler and Pauleit, 2016).

Interestingly, the term 'ecosystem service' received less attention than the term 'biodiversity'. This is consistent with studies in other countries, where biodiversity has been found to be the driver of EbA approaches (Wamsler et al., 2016). The importance given to biodiversity in Germany is probably also related to the fact that the country expects climate change to have severe impacts on biodiversity in the near future (Mosbrugger et al., 2013). The city of Stuttgart, for example, states that biological diversity is particularly threatened by climate change and that negative effects, such as species distribution and behaviour modification, are already noticeable (Amt für Umweltschutz Stuttgart, 2013).

This study also shows that the EbA concept is more widely understood in the research community than in municipal administrations or private companies (the authors of the assessed adaptation strategies). This supports findings of other studies from South Africa and Germany, which reveal that advances in EbA integration are more often found in cities where climate change adaptation research is being carried out (Pasquini and Cowling, 2014; Wamsler, 2015). In this study, Dresden's strategy contained the most references to ecosystem services, which might be due to the fact that its adaptation strategy is the product of a large research project entitled 'REGKLAM' (REGKLAM-Konsortium, 2013).

Furthermore, the variation in the percentage and type of measures found in adaptation strategies suggests that a consistent and comprehensive approach to their selection and integration does not yet exist. In Germany, there is currently no legal requirement to develop an urban adaptation strategy, or official guidelines on how to do it. Existing strategies are therefore the result of voluntary

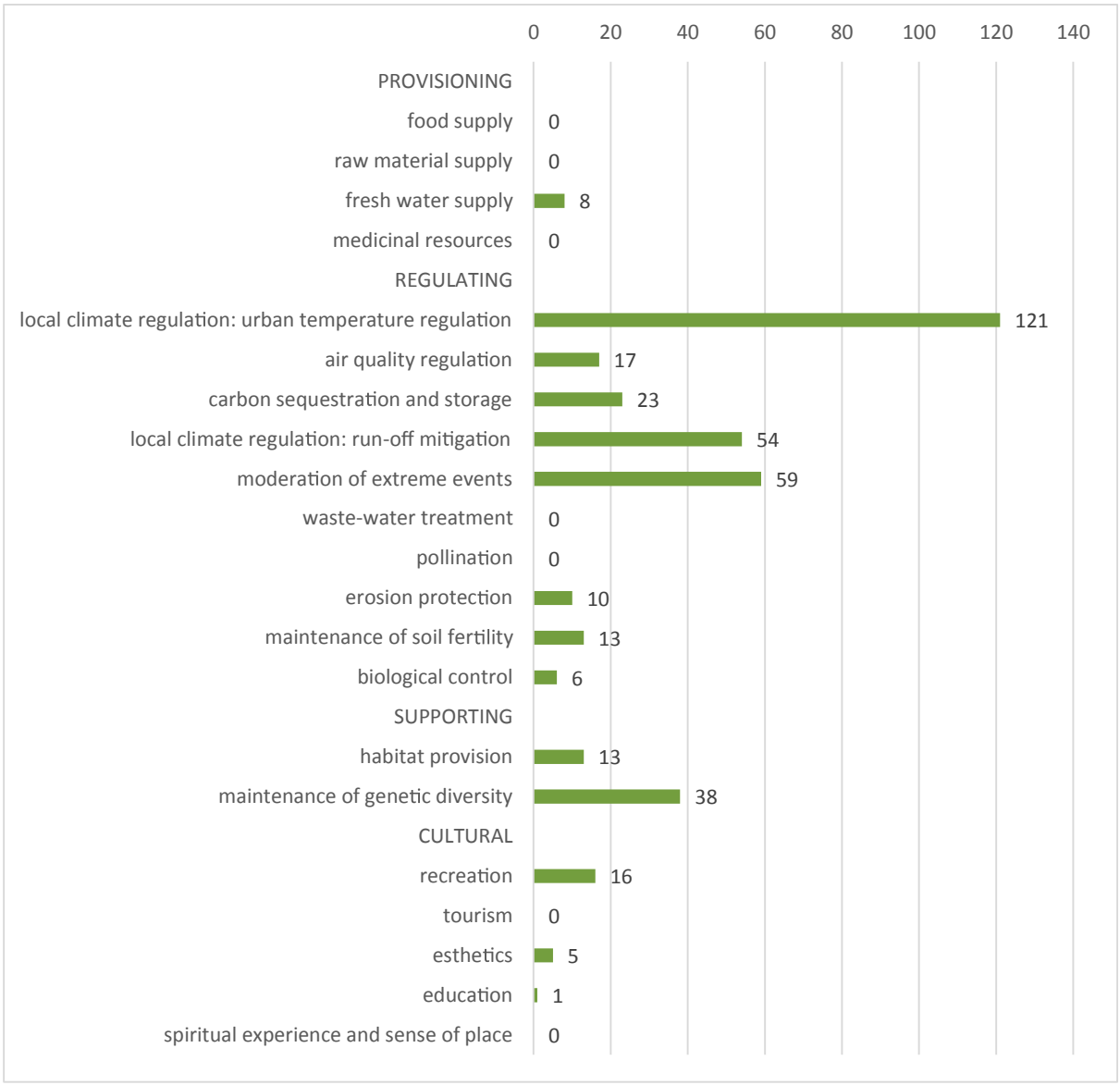


**Fig. 6.** Individual ecosystem services underlying EbA measures.

efforts. This has resulted in a wide array of approaches, and different types of strategies and measures, with different scope (cf. Geneletti and Zardo, 2016).

These findings suggest that clearer guidance and an emphasis on the importance of ecosystems for climate change adaptation is needed in Germany to promote the integration of EbA into urban adaptation planning (Deutsche Bundesregierung, 2011; Pramova et al., 2012; Hansen et al., 2014; Noble et al., 2014). Efforts are currently underway in 22 of the 44 national adaptation programmes included in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) (Pramova et al., 2012; Noble et al., 2014) and EbA is an explicit aim of the German National Adaptation Strategy (Deutsche Bundesregierung, 2011).

### 4.2. Benefits of EbA

This study indicates that local climate regulation is the most frequently named criteria when selecting adaptation strategies and EbA measures, which highlights its importance in practice. This is consistent with the projected climate change impacts of extreme weather events in Germany (Deutsche Bundesregierung, 2008; DWD, 2015). In contrast, urban planning documents tend to focus on supporting services (Hansen et al., 2014). Furthermore, from the groups of provisioning and cultural ecosystem services recreation opportunities are referred to most often. This illustrates that enhancing green infrastructure for climatic purposes creates more recreational facilities and provides a space where citizens can rest during extreme events, e.g. hot summer days.

Almost half of the adaptation strategies that were examined emphasised the multiple functions of EbA. While non-EbA measures have one adaptation benefit (e.g. mechanical shadowing or changing surface albedo), they rarely provide several benefits (EEA, 2012). Our results underline the need for more studies that provide (quantitative) evidence of the multiple benefits (for both adaptation and other areas of urban planning) of EbA (Doswald et al., 2014). The assessment of multi-functionality in urban planning

processes must go beyond a simple 'summing up' of services in order to identify or avoid potential trade-offs (Hansen and Pauleit, 2014).

While cost effectiveness is often cited as a benefit of EbA, compared to technical adaptation measures (Jones et al., 2012; Noble et al., 2014), it was rarely addressed in the documentation. Very little information was provided on the expected costs of the implementation and financing of measures. Exceptions include Munich, which provides approximate costs and Jena, which provides estimates of expenditure (Kurmutz et al., 2012; RGU, 2012).

Focusing on the cost–benefit ratio of EbA measures presented in the literature, Doswald et al. (2014) showed that many measures perform positively when social, environmental and economic benefits are considered. This can be compared to cost–benefit analyses of technical adaptation measures, which are even rarer (e.g. Wang et al., 2014). Regarding the economic valuation of natural goods, Tröltzsch et al. (2012) found that a lack of data makes it difficult to compare the costs and benefits of climate change adaptation measures across sectors.

### 4.3. Implementation of EbA

A prerequisite for the implementation of EbA measures is that the importance of ecosystem services in effective climate change adaptation is acknowledged and disseminated into municipal adaptation strategies (Naturkapital Deutschland, 2014). The strategies examined here acknowledge this by indirectly referring to ecosystem services. The establishment of an adaptation strategy can, in itself, be seen as an integral part of mainstreaming EbA into municipal planning and governance (Wamsler, 2014, 2015), as it is a strategic tool for the systematic integration and implementation of related strategies and measures. All of the cities included in this analysis have advanced EbA mainstreaming by establishing adaptation strategies that promote sectoral integration, and many of them also include specific action plans for local EbA. However, the actual translation of proposed measures into practice requires a comprehensive mainstreaming approach at all levels (local, institutional and inter-institutional), including the establishment of related mechanisms and structures for monitoring, evaluation and learning.

## 5. Conclusions and recommendations

Given the growing importance of EbA in the context of urban planning at the international (Noble et al., 2014), European (EC, 2015), national and local levels (BfN, 2012), this comparative analysis provides timely insights into the integration of EbA into municipal adaptation strategies. While the EbA concept was not referred to directly in the analysed adaptation strategies, references were made to the concept's underlying components. Most references to EbA were included in the strategies' sections that focus on planned adaptation measures. This indicates an emerging recognition that the support of ecosystem services and biodiversity is relevant when implementing urban adaptation planning. 76% of the analysed strategies mentioned at least some kind of EbA measure. However, the ratio of EbA to conventional adaptation options was often low and varied significantly (from 15 to 100%). Only 25% of all strategies highlighted the multiple benefits of EbA, indicating that this aspect is not (yet) seen as an important implementation criterion. Finally, the conceptual framework presented here has proven to be useful in identifying key patterns in the use of EbA in current municipal adaptation strategies in Germany and its comparison to other geographical contexts.

In sum, this study shows that the successful translation of EbA measures into strategic adaptation planning and practice needs further mainstreaming at all levels. It is concluded that better promotion of the EbA concept (e.g. through more distributed urban governance, enhancing top-down policy support, bottom-up activities and science-policy integration) is urgently needed for comprehensive mainstreaming that fosters sustainable development. In fact, the systematic integration of the concepts of ecosystem services and EbA in urban planning requires both greater support from high policy levels and more involvement and cooperation of different stakeholders. Pilot projects and bottom-up initiatives can enhance the uptake of EbA in adaptation strategies and planning, but more research is needed to assess both the benefits and the cost-effectiveness of EbA compared to other adaptation options. Finally, monitoring and learning from the mainstreaming and implementation of EbA in both strategic planning and operation is crucial. Only then can EbA become a relevant alternative to conventional adaptation approaches, and a key pathway to effective and sustainable climate change adaptation.

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## Appendix A. Adaptation strategies published by German cities

| City | Type of adaptation strategy | Publisher | Year | Name |
|---|---|---|---|---|
| Berlin | standalone | Senatsverwaltung für Stadtentwicklung und Umwelt, Berlin | 2011 | Stadtentwicklungsplan Klima - Urbane Lebensqualität im Klimawandel sichern |
| | | Senatsverwaltung für Stadtentwicklung und Umwelt, Berlin | 2013 | Klimaanpassung für Berlin - Maßnahmen und Beispiele |
| Hamburg | standalone | Senat der freien und Hansestadt Hamburg | 2013 | Aktionsplan Anpassung a den Klimawandel |
| München | in mitigation strategy | Referat für Gesundheit und Umwelt, Landeshauptstadt München | 2010 | IHKM – Integriertes Handlungsprogramm Klimaschutz in München |
| | | Referat für Gesundheit und Umwelt, Landeshauptstadt München | 2013 | IHKM Klimaschutzprogramm 2013 Maßnahmenkatalog |

(*continued*)

| City | Type of adaptation strategy | Publisher | Year | Name |
|---|---|---|---|---|
| Köln | standalone | Landesamt für Natur, Umwelt und Verbraucherschutz, Nordrhein-Westphalen | 2013 | Klimawandelgerechte Metropole Köln - Abschlussbericht, LANUV Fachbericht 50 |
| Frankfurt am Main | standalone | Stadt Frankfurt, Koordinierungsgruppe Klimawandel | 2014 | Frankfurter Anpassungsstrategie a den Klimawandel |
| Stuttgart | standalone | Landeshauptstadt Stuttgart, Amt für Umweltschutz, Abteilung Stadtklimatologie in Verbindung mit Abteilung Kommunikation | 2013 | Klimawandel-Anpassungskonzept Stuttgart KLIMAKS |
| Dortmund | standalone | Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westphalen | 2011 | Handbuch Stadtklima - Maßnahmen und Handlungskonzepte für Städte und Ballungsräume zur Anpassung a den Klimawandel |
| Essen | in mitigation strategy | Stadt Essen | 2009 | Integriertes Energie- und Klimakonzept der Stadt Essen - Unsere Stadt, unser Klima |
| Bremen | standalone | Senator für Umwelt, Bau und Verkehr der freien Hansestadt Bremen | 2012 | SUBV Fachkonzept Klimawandel in Bremen - Folgen und Anpassung |
| Dresden | standalone | REGKLAM Konsortium | 2013 | Integriertes Regionales Klimaanpassungsprogramm für die Region Dresden - Grundlagen, Ziele und Maßnahmen |
| Hannover | standalone | – | – | Anpassungsstrategie zum Klimawandel - Informationen zu den Folgen des Klimawandels für die Stadt Hannover und die daraus resultierenden notwendigen Anpassungsmaßnahmen |
| Nürnberg | standalone | Umweltamt der Stadt Nürnberg | 2012 | Handbuch Klimaanpassung - Bausteine für die Nürnberger Anpassungsstrategie |
| Duisburg | standalone | Stadt Duisburg | 2013 | Klimawandelanpassungsstrategie für Duisburg |
| Bochum | standalone | Steinrücke, Monika (Geographisches Institut der Ruhr-Universität Bochum), Stadtplanungs- und Bauordnungsamt der Stadt Bochum | 2012 | Klimaanpassungskonzept Bochum |
| Wuppertal | standalone | – | – | Anpassungsstrategie der Wuppertaler Stadtentwässerung a die Folgen des Klimawandels |
| Bonn | in mitigation strategy | Gertec GmbH Ingenieursgesellschaft | 2013 | Integriertes Klimaschutz- und Anpassungskonzept |
| Karlsruhe | standalone | Umwelt- und Arbeitsschutz, Stadt Karlsruhe | 2013 | Anpassung a den Klimawandel - Bestandsaufnahme und Strategie für die Stadt Karlsruhe |
| Gelsenkirchen | in mitigation strategy | Stadt Gelsenkirchen | 2011 | Integriertes Klimaschutzkonzept Abschlussbericht |
| Chemnitz | in mitigation strategy | Stadt Chemnitz | 2013 | Integriertes Klimaschutzprogramm für die Stadt Chemnitz, detaillierte Fassung |
| Halle (Saale) | in mitigation strategy | Stadt Halle | 2013 | Integriertes kommunales Klimaschutzkonzept |
| Oberhausen | in mitigation strategy | Wuppertal Institut für Klima, Umwelt und Energie, EEB Enerko | 2012 | Energie- und Klimaschutzkonzept für die Stadt Oberhausen, Abschlussbericht |
| Erfurt | in mitigation strategy | Umwelt- und Naturschutzamt, Klimaschutzkoordinator, Landeshauptstadt Erfurt | 2012 | Klimaschutz in Erfurt - Leitbild, Ziele und Handlungskonzept |
| Rostock | standalone | Amt für Umweltschutz der Stadt Rostock | 2012/13 | Rahmenkonzept zur Anpassung a den Klimawandel in der Hansestadt Rostock |
| Saarbrücken | in urban development strategy | Dezernats- und ämterübergreifende Arbeitsgruppe unter Federführung des Baudezernats, Landeshauptstadt Saarbrücken | 2011 | Städtebauliches Entwicklungskonzept für die Landeshauptstadt Saarbrücken |
| Mülheim a. d. Ruhr | in mitigation strategy | Stadt Mühlheim a der Ruhr | 2011 | Klimazone Mühlheim a der Ruhr - Handlungsansätze und Leitgedanken zu Klimaschutz und Klimaanpassung |
| Potsdam | in mitigation strategy | Landeshauptstadt Potsdam | 2010 | Gutachten zum Integrierten Klimaschutzkonzept |
| Solingen | standalone | Stadt Remscheid | 2013 | KlimaschutzTeilkonzept „Anpassung a den Klimawandel für die Städte Solingen und Remscheid“ |
| Darmstadt | in mitigation strategy | Institut Wohnen und Umwelt GmbH, memo consulting | 2013 | Integriertes Klimaschutzkonzept für die Wissenschaftsstadt Darmstadt |
| Würzburg | in mitigation strategy | B.A.U.M. Consult GmbH | 2012 | Integriertes Klimaschutzkonzept für die Stadt Würzburg |
| Offenbach am Main | in mitigation strategy | Stadt Offenbach am Main | 2010 | Integriertes Klimaschutzkonzept Endbericht |
| Bottrop | standalone | Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westphalen | 2011 | Handbuch Stadtklima - Maßnahmen und Handlungskonzepte für Städte und Ballungsräume zur Anpassung a den Klimawandel |
| Recklinghausen | standalone | Stadt Recklinghausen | 2012 | Integriertes Klimaschutzkonzept der Stadt Recklinghausen, Abschlussbericht |

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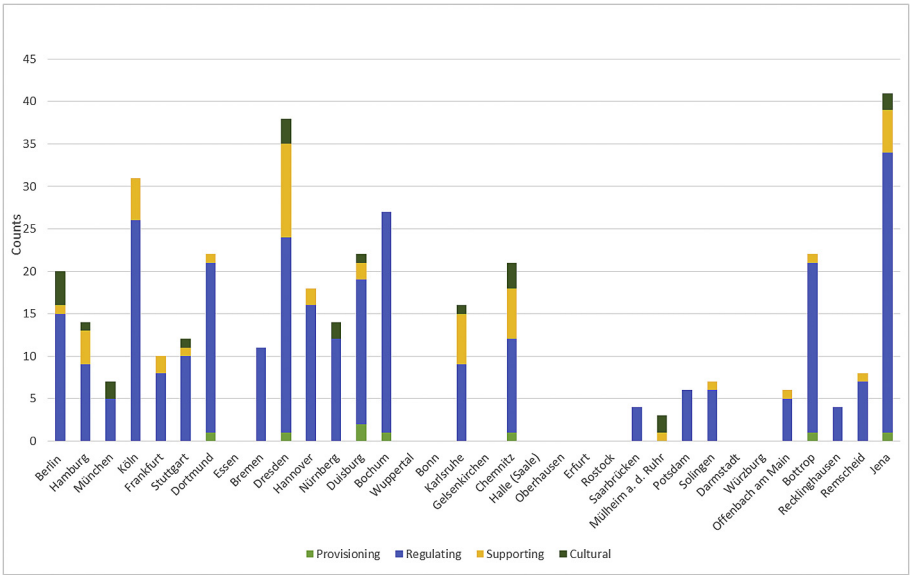
(*continued*)

| City | Type of adaptation strategy | Publisher | Year | Name |
|---|---|---|---|---|
| Remscheid | standalone | Stadt Remscheid | 2013 | KlimaschutzTeilkonzept „Anpassung a den Klimawandel für die Städte Solingen und Remscheid“ |
| Jena | standalone | ThINK - Thüringer Institut für Nachhaltigkeit und Klimaschutz | 2012 | Handbuch Klimawandelgerechte Stadtentwicklung für Jena - ExWoSt Modellprojekt - Jenaer Klimaanpassungsstrategie JenKAS |
| | | ThINK - Thüringer Institut für Nachhaltigkeit und Klimaschutz | 2013 | Gesamtkatalog der Handlungsempfehlungen zum Handbuch einer klimawandelgerechten Stadtentwicklung in Jena |

## Appendix B. Number and type of ecosystem services underlying EbA measures in adaptation strategies

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